



Miscellaneous

The effect of using a pre-dive checklist on the incidence of diving mishaps in recreational scuba diving: a cluster-randomized trial

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Abstract

Background: Scuba diving mishaps, caused by equipment problems or human errors, increase the occurrence of injuries and fatalities while diving. Pre-dive checklists may mitigate mishaps. This study evaluated the effect of using a pre-dive checklist on the incidence of diving mishaps in recreational divers.

Methods: A multi-location cluster-randomized trial with parallel groups and allocation concealment was conducted between 1 June and 17 August 2012. The participants had to be at least 18 years of age, permitted to dive by the dive operator and planning to dive on the day of participation. They were recruited at the pier and dive boats at four locations. The intervention group received a pre-dive checklist and post-dive log. The control group received a post-dive log only. The outcomes, self-reported major and minor mishaps, were prompted by a post-dive questionnaire. Mishap rates per 100 dives were compared using Poisson regression with generalized estimating equations. Intent-to-treat, per-protocol and marginal structural model analyses were conducted.

Results: A total of 1043 divers (intervention = 617; control = 426) made 2041 dives, on 70 location-days (intervention = 40; control = 30) at four locations. Compared with the control group, the incidence of major mishaps decreased in the intervention group by 36%, minor mishaps by 26% and all mishaps by 32%. On average, there was one fewer mishap in every 25 intervention dives.

Conclusions: In this trial, pre-dive checklist use prevented mishaps which could lead to injuries and fatalities. Pre-dive checklists can increase diving safety and their use should be promoted.

Trial Registration: ClinicalTrials.gov ID NCT01960738.

Key words: Injury prevention, sports diving, safety, intervention, human factors

Key Messages

- In this trial, the use of pre-dive checklists decreased the incidence of mishaps in recreational scuba diving.
- Training agencies, dive shops, instructors and other diving industry partners should promote the use of pre-dive checklists in the diving community.
- A widespread adoption of pre-dive checklists in recreational scuba diving has the potential to prevent a substantial number of diving-related injuries and fatalities and the associated financial burden to the diving community.

Introduction

A checklist is a simple and effective tool used to reduce human error and equipment malfunction that may cause injury. In aviation, checklists have played a dominant role in the safety culture for more than seven decades. Pilots and crew members of military and commercial airliners are required to complete pre-flight checklists for equipment, procedures and even individual health and mental status, leading to safer flights. This also provides an opportunity for continuous scrutiny and amendment of flying procedures.^{1–3} In surgery, preoperative and postoperative checklists substantially reduce postoperative mortality and morbidity.⁴

In recreational scuba diving, pre-dive checklists are mostly used during training dives. There is no gold-standard pre-dive checklist, and training agencies use different checklists, none of which has been systematically evaluated for effectiveness. The prevalence of written pre-dive checklist use in recreational scuba diving is not known, but is assumed to be low.

Recreational scuba diving is a popular sport. In 2000 there were about 2.5 million scuba divers in the USA.⁵ The mainly self-regulated industry of recreational scuba diving includes training agencies, dive operators, dive resorts and equipment and travel industries. The Professional Association of Diving Instructors alone certified more than 11.5 million divers during 1999–2008.⁶ Many training agencies set the minimum age limit for diving in open water at 12 years with no upper limit. Commonly, training in diving physiology, equipment and management of pressure changes is provided in small modules, and divers are certified for life after the first basic module; neither advanced training nor periodic re-certification are mandatory.

In a recent Divers Alert Network (DAN) study, the overall self-reported injury rate among recreational scuba divers was 3/100 dives.⁷ Diving injuries amount to a significant financial burden on the diving community and healthcare providers, with limited resources due to treatment costs, residual disability, loss of productivity and/or death.⁸ DAN reports 80–90 diving-related deaths among the US and Canadian divers every year.⁹ The diving-related fatality rate among DAN membership is estimated at 16.4/100 000 person-years.⁹

Reconstructions of diving fatalities suggest that many are triggered by preventable mishaps.^{10,11} Mishaps are unplanned and unwanted events that increase the risk of an injury. They are caused by human errors,^{12–14} equipment failures^{15–17} and adverse environmental factors.¹⁸ In one study, the incidence of three common mishaps—low to out of air, rapid ascent, loss of buoyancy control—was 2.17/100 dives.¹⁹ Forgetting, omitting or neglecting adequate pre-dive preparation, coupled with increasing levels of stress^{13,20,21} and complexity of equipment^{15–17,21,22} may lead to mishaps and injuries. Interventions aimed at preventing mishaps may reduce injuries and fatalities.^{10–12}

The authors evaluated the effect of using a pre-dive checklist on the incidence of scuba diving mishaps among recreational divers.

Methods

A cluster-randomized trial design was used to assess the effect of using a pre-dive checklist on the incidence of diving mishaps in recreational scuba divers. Participants were cluster-randomized by location-day, that is, on each day enrolled participants at the same location were all in the control or intervention group. Cluster-randomization prevented cross-contamination of the intervention; however, the participants diving on the same location-day may not have independent outcomes.

The study was conducted by DAN research assistants at participating dive shops in North Carolina, Cozumel and the Cayman Islands between 1 June 2012 and 17 August 2012. DAN is a not-for-profit membership organization that provides medical assistance and education to divers and conducts diving medical research. Four trained DAN research assistants, one each in North Carolina and Cayman and two in Cozumel, recruited participants and collected data at seven partnering dive shops.

There were four study instruments: the intervention form (pre-dive checklist+ post-dive log), the control form (post-dive log), contact-information form and outcomes questionnaire (intervention and control form are available as [online supplements](#) at *IJE* online, and copies of other

materials are available upon request). The contact-information form was used to enrol and track participants and record their age, sex and racial/ethnic background. The outcomes questionnaire included a list of potential mishaps identified by experts using the 'diving incident report form' from an ongoing DAN Asia Pacific study,²² brief medical history, diving history, height and weight. It was given to both the groups at the end of their dives.

For each location, separate packets of study materials were assembled. Half of the packets were intervention. Each packet contained 30 sets of consent forms, laminated intervention or control forms, outcomes questionnaires, marker pens and one contact-information form. Packets were randomized beforehand at DAN using an SAS random number generator, and then sequentially numbered. The study arm of each randomly numbered packet was noted on a spreadsheet for cross-checking at the end of data collection. Interns who administered the study picked up a sequentially numbered packet every day to enrol the participants.

A participating diver had to: have a valid diver certification, be 18 years of age or older, be planning to dive on the day of recruitment, be deemed fit for diving by the dive operator and have working knowledge of English. The divers were briefed about the study on the dive boat or pier; those agreeing to participate were asked to sign the consent to participate and provide demographic information. The participants received either the intervention form or the control form and instructions on how to use them. When the participants completed their dives, or upon their return to the pier, interns collected the study forms and asked the participants to answer the outcomes questionnaire. Each diver's participant number was recorded on their intervention or control forms, outcomes questionnaire and contact information form, which allowed linking their records. The interns entered the data online. Data were monitored weekly by the principal investigator for completeness and accuracy.

The estimated sample size to achieve 90% power and detect a 50% reduction in the incidence of mishaps, at 10/100 dives baseline mishap rate and alpha of 0.05, with an intervention to control allocation ratio of one, while accounting for within-location day and between location-day variance for clustering of dives, was 2193 dives (1097 intervention and 1097 control). The within-diver clustering of dives was not accounted for.

The research hypothesis was not disclosed to the participants during the consent. They were not told that they were participating in an intervention trial or that they were being randomly assigned to use the pre-dive checklist, because disclosing this information could have changed their behaviour and may have obscured the effect of the

checklist.^{23,24} The trial had allocation concealment: the interns were only allowed to allocate the envelopes in the predetermined randomized order.²⁵ They did not know which envelope was intervention or control until they opened it on subsequent recruitment days.

This study was approved by the institutional review boards (IRB) of DAN # 009-12 on 27 March 2012 and the University of North Carolina (UNC) # 12-1051 on 29 May 2012, and further renewed by DAN IRB and UNC IRB in 2013, 2014, and 2015.

Statistical methods

Diving experts at DAN classified the mishaps as major or minor based on their potential to lead to serious injury. The rates of major mishaps, minor mishaps and all mishaps (major plus minor) were reported as the number of mishaps per 100 dives.

Each participant reported the number of dives and the number of mishaps cumulatively for their participation day. Hence, mishap information is available for each individual, rather than for each dive. Since the unit of exposure is a dive, mishap rates are calculated per dive and not per diver. Poisson regression was used to compare the incidence rates of mishaps in the intervention and control groups. The non-independence of observations within a location-day cluster was addressed using generalized estimating equations (GEE).²⁶

Intent-to-treat (ITT) analysis was used to estimate the effect of receiving the checklist. Per-protocol (PP) analysis and marginal structural models (MSM) were used to estimate the effect of using the checklist. The crude incidence rate of mishaps for both intervention and control groups, rate difference and rate ratios were estimated. The crude 'number needed to treat' (NNT), that is number of dives using the checklist needed to reduce the number of mishaps by 1, was calculated as $1/\text{crude-rate-difference}$.

Adjusted measures of the intervention effect were calculated because randomization only balances potential confounders on average.²⁷ The potential confounders were sex, age, body mass index (BMI), race, poor visibility, high current, animal attack, average annual dives, use of a diver's own written checklist (hereafter referred to as self-checklist) and years of diving certification. A parsimonious set of adjustment variables to control confounding was derived by backward elimination. Any variable seen favourably in precision-validity trade-off was retained in the model. Specifically, a covariate was retained in the model if the change in the estimated variance of the treatment coefficient was negative upon adjustment for that covariate or positive but smaller than the squared change in the estimate of the treatment coefficient. At each step, change was

measured in relation to the initial model containing all the selected covariates.

Based on the precision-validity trade-off, the final adjusted models controlled for sex (male/ female), race (White/ non-White), poor visibility (yes/no), high current (yes/no), animal attack (yes/no), average annual dives (linear quadratic) and the use of a self-checklist (yes/no).

We evaluated interaction between the intervention and divers' use of self-checklist. We reported ratio of rate ratios, their 95% confidence intervals and corresponding *P*-value from the regression models as a measure of multiplicative interaction. Ratio of rate ratios can be calculated as $(R_{11}/R_{01})/(R_{10}/R_{00})$; here R_{11} = rate of mishaps in the intervention participants who reported using self-checklist, R_{01} = rate of mishaps in the controls who reported using self-checklist, R_{10} = rate of mishaps in the intervention participants who reported not using self-checklist and R_{00} = rate of mishaps in the controls who reported not using a self-checklist. We also reported two measures of additive interaction: (i) the difference of rate differences, also known as interaction contrast (IC), calculated as $(R_{11} - R_{01}) - (R_{10} - R_{00})$; and (ii) the relative excess rate due to interaction (RERI), also known as interaction constant ratio, calculated as $(R_{11}/R_{00}) - (R_{01}/R_{00}) - (R_{10}/R_{00}) + 1$ or IC/R_{00} .²⁸ Hosmer Lemeshow additive interaction calculator was used to calculate the 95% confidence interval (CI) for RERI.³⁰

Poor adherence could reduce the impact of the intervention. To address this, an adherence variable was developed using three criteria. First, a diver must have noted the starting tank pressure of their first dive on the checklist. Next, the diver must have indicated a written pre-dive gas management plan on the checklist. Last, the diver must have checked at least 10 checkboxes on the checklist. All control group participants were considered adherent because they dived as usual. Crude and adjusted per protocol analyses were conducted by removing the non-adherent divers from the analysis.

Marginal structural models were used to account for non-adherence. Inverse probability weights for adherence were calculated for all intervention group participants, whereas the control group participants were given a weight of one.²⁹ The adherence weighting among the intervention group participants is given by:

$$w = P(\text{adherence}) / P(\text{adherence} \mid \text{gender, age, race, poor visibility, high current, animal attack, average annual dives, history of hypertension, history of high cholesterol})$$

where w = weight, P = probability.

The adherence probabilities were derived using logistic regression. Crude and adjusted Poisson regression models

were then weighted using these inverse probability weights. All statistical analyses were conducted using SAS 9.3 (SAS Institute, Cary, NC, USA).

Results

Participants were enrolled on 40 intervention and 30 control location-days (intervention allocation ratio: 1.33). A total of 1160 participants were enrolled, of whom 9 withdrew, 31 were excluded because they did not complete the study, 77 were lost to follow-up and 1043 completed the study (Figure 1). Participants who withdrew, did not complete the study or were lost to follow-up, did not complete the outcomes questionnaire and did not turn in the intervention/control form. These participants (10.1%) were excluded from the analysis. The mishap rate in this group is unknown because of lack of outcome information.

Although the trial was designed to have equal sample sizes in the intervention and control groups, the total numbers of location-days, divers and dives were greater in the intervention than the control group (Figure 1 and Table 1). The imbalance in number of location-days occurred at two locations (Supplementary Table 1, available as Supplementary data at *IJE* online) because each DAN research assistant received a different randomized sequence of intervention and control location-days. By chance, the randomization sequence at location 1 and 2 had more intervention days in the beginning and we had to stop recruiting at 1200 divers (IRB regulation), at which time locations 1 and 2 had collected more intervention location-days. The numbers of divers and dives in the two groups differed at all locations because the number of recruited divers varied between 8 and 25 divers per day (mean = 15.4), and the number of dives made by divers varied between 0 and 6 per diver (mean = 2.0).

Over two-thirds of the participants were males, 94.8% were White, and the median age was 43 years (Table 1). Only 6.6% of all participants reported regularly using a self-checklist. Divers made a total of 2041 dives ranging from 0 to 6 dives per day; 89.5% dived twice; and 43 divers chose to not dive, 22 of whom were in the control group and 21 in the intervention group.

About a quarter of all participants ($n=260$) reported one or more major or minor mishap, ranging from 1 to 7 per person. The overall rate of major mishaps was 8.6/100 dives. Rapid ascent (3.6/100 dives), lost buddy contact (2.5/100 dives) and low to out of air (1.0/100 dives) were the most common. The overall rate of minor mishaps was 8.5/100 dives. Changed buoyancy (3.1/100 dives), mask squeeze (2.4/100 dives) and being unable to clear the mask

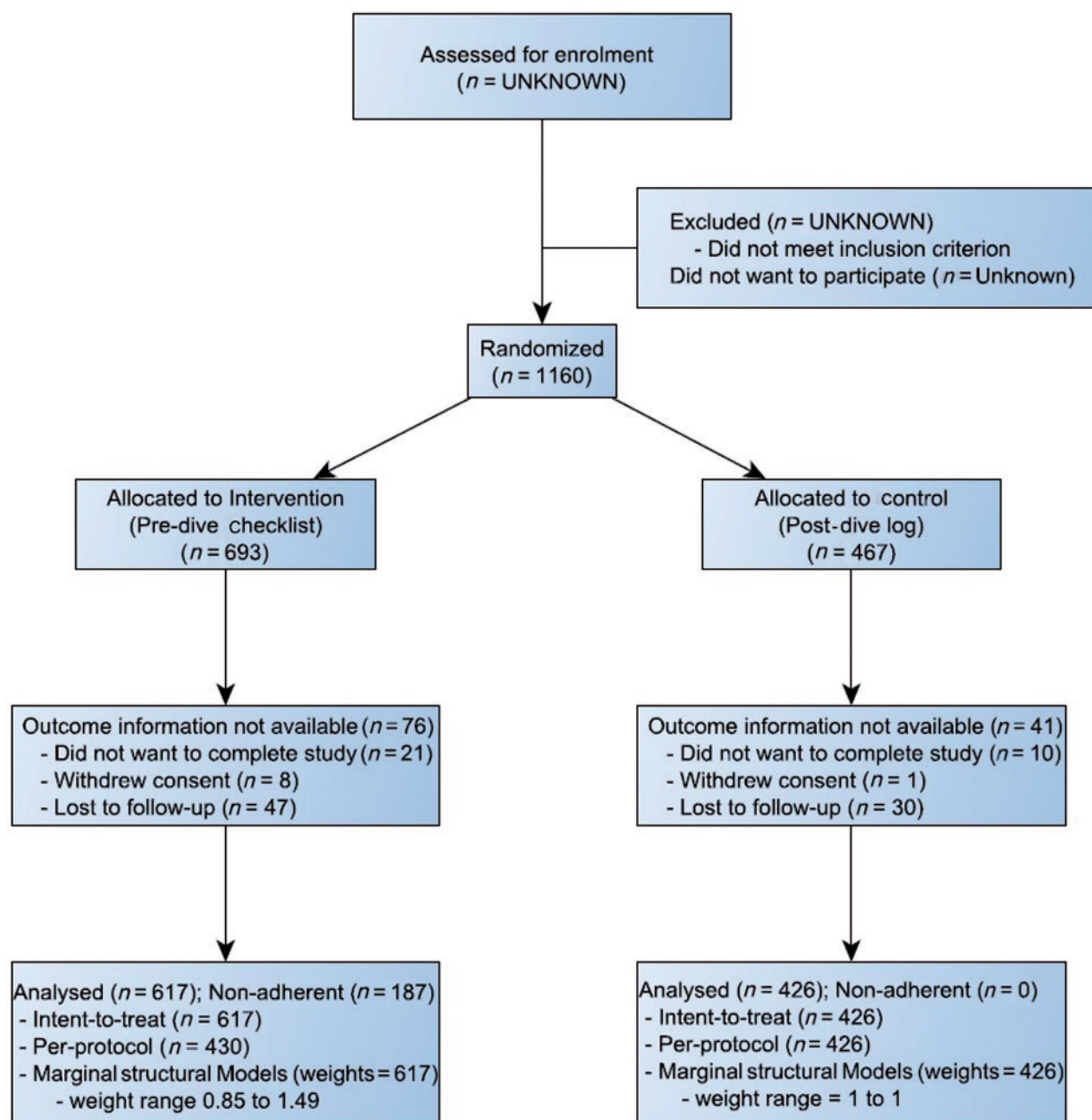


Figure 1. Distribution of participants based on the assigned group.

(0.8/100 dives) were the most common. None of the enrolled divers was injured during the study (Table 2).

The crude ITT rates of major mishaps were 7.5 per 100 dives in the intervention group and 10.2 per 100 dives in the control group (Table 2), yielding a crude rate difference of 2.7 mishaps per 100 dives and an adjusted ITT rate ratio (RR) of 0.64 (95% CI: 0.46, 0.87) (Table 3).

The number needed to treat (NNT) was 37 dives, indicating that one major mishap was prevented by using the checklist beforehand in 37 dives. The crude ITT rate of all mishaps in the intervention group was 15.4 per 100 dives,

and 19.5 per 100 dives in the control group, producing a crude rate difference of 4.1 mishaps per 100 dives and an adjusted ITT RR of 0.68 (95% CI: 0.50, 0.93); the NNT was 24.4 dives.

The intervention effect on major mishaps differed between divers who did and did not use their own self-checklist in both the ITT and MSM analyses on the multiplicative scale (Table 3), and on the additive scale (Supplementary Table 2, available as Supplementary data at *IJE* online). The ITT and MSM analyses suggest that the intervention reduced the incidence of major mishaps by

Table 1. Diver demographics based on analysis approach and trial arm

	Intent-to-treat		Per-protocol	
	Intervention	Control	Intervention	Control
Total divers	617	426	430	426
Dives				
Total	1201	840	840	840
Location 1	243	181	184	181
Location 2	423	170	320	170
Location 3	281	268	196	268
Location 4	254	221	140	221
	Mean (median)	Mean (median)	Mean (median)	Mean (median)
Average annual dives	22.8 (10)	37.0 (10)	24.6 (10)	37.0 (10)
BMI	26.4 (26)	26.6 (26)	26.4 (26)	26.6 (26)
Age (years)	41.5 (43)	42.4 (44)	42.1 (43)	42.4 (44)
	%	%	%	%
Males	66.1	70.4	67.7	70.4
White	93.8	96.2	94.7	96.2
Self-checklist	5.8	7.7	7.2	7.7
Animal attack	0.5	0.2	0.5	0.2
High current	18.8	17.8	17.9	17.8
Poor visibility	9.9	6.8	9.1	6.8

Location 1, Cayman Islands; location 2, Cozumel 1; Location 3, Cozumel 2; Location 4, North Carolina; %, per 100 divers; BMI, body mass index.

42% and the incidence of all mishaps by 36%, among those who did not use self-checklists. However, among those who used self-checklists, those in the intervention group reported twice as many mishaps as those in the control group (RR: 2.03, 95% CI: 0.72, 5.69) (Table 3). The incidence of major mishaps and all mishaps in the doubly exposed, i.e. those in the intervention group who reported using their own checklist, was similar to the doubly unexposed, i.e. those who did not receive the intervention and did not have their own checklist (Supplementary Table 2).

Discussion

To our knowledge, this is the first randomized trial evaluating the ability of a pre-dive checklist to reduce diving mishaps among recreational divers. In a population of divers from four sites in North Carolina, Cayman and Mexico, the intervention group experienced approximately 36% fewer major mishaps, 26% fewer minor mishaps and 32% fewer major and minor mishaps combined, compared with the control group. Although the generalizability of the effectiveness of this intervention in other populations, locations and diving conditions is unknown, the trial results support the use of pre-dive checklists to promote safety in recreational diving. Diving studies have long noted that a large number of injuries occur as a result of

preventable mishaps.^{9,10,12} A pre-dive checklist encompasses basic safety principles and may prevent diving-specific and non-specific injuries by reducing the incidence of diving mishaps. The potential benefits of promoting pre-dive checklists are due, in part, to the low frequency of self-checklist use in recreational scuba diving.

The NNT for major mishaps was 37, suggesting that had the intervention group not received the intervention, they would have experienced 32 additional major mishaps. The NNT for major and minor mishaps combined suggests that 49 total mishaps were prevented in the intervention group.

From the interaction analyses, we see that the intervention has a preventive effect among participants without self-checklist, but among participants with self-checklist the intervention group has a higher incidence of mishaps than the control group (Table 3). However, this may be an artefact due to small sample size and to over-reporting of mishaps as a result of the heightened awareness among divers who already used some form of checklist and were then given an intervention checklist. This hypothesis may be further supported by the fact that only 14% doubly-exposed divers were non-compliant with the intervention checklist as opposed to 31% non-compliant among those who were exposed to intervention only. Furthermore, we see that the rate of mishaps in the intervention group participants with self-checklist (doubly exposed) was similar to the control

Table 2. Number of mishaps and crude incidence rates of mishaps based on the analysis approach and trial arm

Types of mishaps	Intent-to-treat				Per-protocol			
	Intervention (1201 dives)		Control (840 dives)		Intervention (840 dives)		Control (840 dives)	
	No.	Rate ^a	No.	Rate ^a	No.	Rate ^a	No.	Rate ^a
Major mishaps	90	7.5	86	10.2	63	7.5	86	10.2
Rapid ascent ^b	37	3.1	37	4.4	24	2.9	37	4.4
Lost buddy contact	29	2.4	22	2.6	22	2.6	22	2.6
Low to out of air	11	0.9	09	1.1	08	1.0	09	1.1
Entanglement/entrapment	02	0.2	09	1.1	02	0.2	09	1.1
Buddy breathing	06	0.5	02	0.2	03	0.4	02	0.2
Spontaneous inflation	01	0.1	05	0.6	01	0.1	05	0.6
Second-stage regulator malfunction	04	0.3	02	0.2	03	0.4	02	0.2
Minor mishaps	95	7.9	78	9.3	66	7.9	78	9.3
Dive suit changed buoyancy	35	2.9	29	3.5	27	3.2	29	3.5
Mask squeeze	26	2.2	23	2.7	17	2.0	23	2.7
Unable to clear mask	11	0.9	06	0.7	07	0.8	06	0.7
Buddy mismatch	08	0.7	07	0.8	06	0.7	07	0.8
Fins lost/loose/dislodged	04	0.3	06	0.7	01	0.1	06	0.7
Air not turned on / not fully on	04	0.3	03	0.4	04	0.5	03	0.4
Fins strap broke	05	0.4	02	0.2	04	0.5	02	0.2
Weights belt/weights dropped	02	0.2	02	0.2	00	0.0	02	0.2
Mask strap broke	00	0.0	00	0.0	00	0.0	00	0.0
Unable to release weights	00	0.0	00	0.0	00	0.0	00	0.0
Total mishaps (Major + minor)	185	15.4	30	19.5	129	15.4	30	19.5

^aRate per 100 dives.^bIncludes diver-reported and computer-recorded rapid ascent.

group participants without self-checklist (doubly unexposed), suggesting a cancelling of protective effects of the intervention and self-checklist (Supplementary Table 2).²⁸

Scuba diving became a popular recreational activity after WWII. Injury prevention efforts in this sport have traditionally targeted severe injuries such as decompression sickness (DCS), pulmonary barotrauma and arterial gas embolism (AGE). These prevention efforts include diving education and use of dive computers, oxygen-enriched-air, flying after diving guidelines, conservative diving practices, first-aid surface oxygen and banning emergency free ascent during training dives.^{31–36} However, most fatalities occur due to causes other than DCS or AGE.^{8,10} Behavioral interventions allow divers to actively participate in ensuring their own safety. Promotion of conservative diving to mitigate DCS is the only behavioural diving intervention adopted thus far.³⁴

Limitations

There was unequal distribution of intervention and control location-days at locations 1 and 2, which could have been avoided to some extent by blocked-randomization, which was not used. We conducted sensitivity analyses to explore the effect of this unequal distribution in our study. The

crude and adjusted results (Supplementary Tables 3 and 4, available as Supplementary data at *IJE* online) suggest that our results are not sensitive to this imbalance, which is to say that we would have still observed similar results had there been no imbalance.

Intervention was randomized by location-days to eliminate cross-contamination; however, it introduced clustering. GEE was used to control the within-location-day clustering. However, there was also clustering on the level of the diver because 92% of the divers dived more than once. This is a limitation that we could not address because outcome information was collected at the diver level, not separately for each dive; doing so would have disclosed the study hypothesis at the risk of contaminating the results. Similarly, information about environmental factors that may vary by dive, such as sea current and visibility, is not available for each dive.

The study was conducted in the warm Atlantic and Caribbean waters, during summer, in daytime and only among recreational scuba divers. The current, visibility and wild animal populations in other regions may vary greatly, and diving conditions differ greatly during other seasons, which limits generalizability. Similarly, the results cannot be generalized to technical divers, seafood harvesters, navy divers or night dives.

Table 3. Adjusted rate ratios for the effect of intervention on the incidence of mishaps

Outcomes	Analysis approach	Adjusted RR ^a (95% CI) All intervention vs all controls	Adjusted intervention vs control RR ^b (95% CI)		Ratio of rate ratios ^d (95% CI)	P-value for interaction
			Among participants without self-checklist	Among participants with self-checklist ^c		
Major mishaps	ITT	0.62 (0.45, 0.87)	0.57 (0.41, 0.80)	2.48 (0.74, 8.31)	4.35 (1.24, 15.31)	0.023
	PP	0.64 (0.46, 0.90)	0.61 (0.43, 0.86)	1.82 (0.47, 1.95)	3.00 (0.73, 12.33)	0.129
	MSM	0.63 (0.46, 0.87)	0.58 (0.41, 0.80)	2.41 (0.71, 8.18)	4.19 (1.17, 14.97)	0.029
Minor mishaps	ITT	0.74 (0.48, 1.13)	0.71 (0.46, 1.08)	1.50 (.32, 7.00)	2.11 (0.48, 9.37)	0.327
	PP	0.74 (0.48, 1.15)	0.71 (0.46, 1.10)	1.45 (0.27, 7.69)	2.04 (0.40, 10.45)	0.397
	MSM	0.74 (0.48, 1.12)	0.71 (0.46, 1.08)	1.50 (0.33, 6.92)	2.11 (0.49, 9.22)	0.321
All mishaps	ITT	0.68 (0.50, 0.93)	0.64 (0.46, 0.88)	2.03 (0.72, 5.69)	3.19 (1.14, 8.90)	0.028
	PP	0.69 (0.50, 0.95)	0.66 (0.47, 0.91)	1.71 (0.54, 5.41)	2.60 (0.82, 8.21)	0.106
	MSM	0.68 (0.50, 0.93)	0.64 (0.46, 0.88)	1.98 (0.70, 5.60)	3.10 (1.10, 8.74)	0.033

RR, rate ratio; ITT, intent-to-treat; PP, per-protocol; MSM, marginal structural models.

^aAdjusted for sex (binary), race (binary—White/ non-White), poor visibility (binary), high current (binary), animal attack (binary), average annual dives (linear quadratic) and use of a written self-checklist other than the intervention checklist (binary).

^bAdjusted for sex (binary), race (binary—White/ non-White), poor visibility (binary), high current (binary), animal attack (binary), average annual dives (linear quadratic), use of a written self-checklist other than the intervention checklist (binary) and interaction between intervention and self-checklist.

^cBased on 36 intervention divers and 69 intervention dives, and 33 control divers who used written self-checklists and 59 control dives.

^dDefined as adjusted intervention vs control rate ratio among participants with self-checklist divided by adjusted intervention vs control rate ratio among participants without self-checklist.

It is also possible that the act of filling out a pre-dive form onboard a boat, regardless of its substance, could produce seasickness, distraction or changes in consciousness about diving safety. A trial evaluating these possibilities would require use of a sham intervention. Future studies could adopt such an approach if difference between use of a pre-dive checklist and use of other types of forms is considered to be of interest.

Conclusions

This trial suggests that use of a pre-dive checklist prevented 30–40% of mishaps. If this effect is generalizable and pre-dive checklists were widely used in recreational diving, a substantial reduction in injuries and fatalities could be achieved. We recommend that dive training agencies, instructors, shops, operators and boat captains promote the use of pre-dive checklists among recreational divers. Future research could evaluate best practices for checklist design, promotion and use. Pre-dive checklists should become a cornerstone of the scuba diving safety culture.

Supplementary Data

Supplementary data are available at *IJE* online.

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Conflicts of interest: None declared.

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